WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
CONTRACT ADMINISTRATION DIVISION

MATERIALS PROCEDURE

GUIDE TO DESIGNING HOT-MIX ASPHALT USING THE MARSHALL DESIGN METHOD

1.0 PURPOSE

1.1 To establish an approved Marshall method design system, test procedures, and evaluation criteria for hot-mix asphalt (HMA). If recycled asphalt pavement (RAP) is used in the design, refer to MP 401.02.24 for additional guidance.

2.0 SCOPE

2.1 This procedure is applicable to design tests conducted for the purpose of establishing mixture proportions for HMA using the Marshall mix design method. Any changes in mix design volumetric requirements included in the following sections will not affect any mix designs that were approved for use prior to the last reissue date of this Materials Procedure.

3.0 APPLICABLE DOCUMENTS

3.1 AASHTO T166: Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens

3.2 AASHTO T209: Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures

3.3 AASHTO T245: Resistance to Plastic Flow of Bituminous Mixtures Using the Marshall Apparatus

3.4 AASHTO T269: Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures

3.5 ASTM D5581: Resistance to Plastic Flow of Bituminous Mixtures Using the Marshall Apparatus [6 inch (150 mm) -Diameter Specimen]

3.6 Asphalt Institute MS-2 Manual: Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types

4.0 TESTING REQUIREMENTS

4.1 The laboratory performing the design shall be a Division approved laboratory. To obtain Division approval, a laboratory must demonstrate that they are equipped, staffed and managed, for batching and testing hot-mix asphalt in accordance with the procedures of this Materials Procedure. This shall be accomplished by submitting a copy of their latest report of inspection by the AASHTO Materials Reference Laboratory (AMRL) to the District Materials Section. They must also submit a letter detailing the actions taken to correct any deficiencies noted in the test procedures listed below. The District will forward this information to the Contract Administration Division, Materials Section. It is also required that the design laboratory request to be included on AMRL's routine schedule of inspections which is usually every 20 to 24 months in order to maintain their approval status.

(1) AASHTO T245 - Resistance to Plastic Flow of Bituminous Mixtures Using the Marshall Apparatus
(2) AASHTO T166 - Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
(3) AASHTO T209 - Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
(4) AASHTO T27* - Sieve Analysis of Fine and Coarse Aggregates
(5) AASHTO T11* - Materials Finer Than No. 200 (75 µm) Sieve in Mineral Aggregates by Washing
(6) AASHTO T84 - Specific Gravity and Absorption of Fine Aggregate
(7) AASHTO T85 - Specific Gravity and Absorption of Coarse Aggregate

* AASHTO T30, Mechanical Analysis of Extracted Aggregate, may be substituted for T27 and T11 if the laboratory is using AASHTO T164, Quantitative Extraction of Bitumen from Bituminous Paving Mixtures, or T308, Asphalt Content of HMA by the Ignition Method, for determining asphalt content of hot-mix asphalt.

An essential portion of the staffing requirement is a technician who has attended and successfully completed a Division approved class on Marshall mix design. Proof of attendance must be provided. A list of the approved design laboratories and design technicians will be maintained by the Division.

4.2 The required mix design properties are:

4.2.1 Stability: AASHTO T245 or ASTM D5581 as applicable.

4.2.2 Flow: AASHTO T245 or ASTM D5581 as applicable.

4.2.3 Air Voids: AASHTO T269

4.2.4 Voids in Mineral Aggregate (VMA): Asphalt Institute MS-2 Manual

4.2.5 Voids Filled With Asphalt (VFA): Asphalt Institute MS-2 Manual

4.2.6 The fines-to-asphalt ratio shall be within the range of 0.6 to 1.2 based on the optimum asphalt content of the mix.

4.3 A series of test specimens shall be prepared for a range of different asphalt contents so that the test data curves show a well-defined "optimum" value. Samples shall be fabricated to include a range of asphalt contents of at least 2% at intervals not to exceed 0.5%.

4.4 Test specimens shall be fabricated from materials of the same sources and types as proposed in the plant mix formula (PMF). The gradation of the combined aggregates used in the test samples shall be the same as that proposed in the plant mix formula and shall meet the requirements of Table 401.4.2 of the Standard Specifications. The percent passing each sieve contained in Table 401.4.2, from the nominal maximum size down to the No. 200 (75 µm), shall be included in all gradation calculations.

4.5 The gradation of each aggregate size from each source used in the design shall be determined from an average of at least three individual gradations of each material from the stockpile at the plant or from material supplied by the aggregate producer. The aggregates shall be sampled in accordance with MP 700.00.06.

4.6 A minimum of three compacted test specimens for each combination of aggregates and asphalt content are required.

4.7 Immediately after the Marshall test specimens are prepared in the mixing bowl, they shall be placed in closed containers and oven aged for two hours before compacting. The oven temperature shall be set within the compaction temperature range established by the temperature-viscosity chart. The specimen prepared for determining the maximum specific gravity shall be oven aged in the same manner before testing.

4.8 Mixtures shall be designed in accordance with the criteria set forth in Table 401.02.22A and Table 401.02.22B unless otherwise indicated in the contract documents.

TABLE 401.02.22A
MARSHALL METHOD MIX DESIGN CRITERIA

Design Criteria (Note 1)	**Medium Traffic Design** (Note 2)	**Heavy Traffic Design**	**Base-I Heavy Traffic Design** (Note 3)
Compaction, number of blows each end of specimen	50	75	112
Stability (Newtons) minimum	5,300	8,000	13,300
Flow (0.25 mm) (Note 4)	8 – 16	8 – 14	12 – 21
Air Voids (%)	3 – 5	3 – 5	3 – 6
Voids Filled With Asphalt (%)	65 – 78	(Note 5) 65 – 75	63 – 75

Note 1: A medium traffic design will typically be used on pavements with a 20 year projected design ESAL value of less than 3 million. A heavy traffic design will be used on pavements with a 20 year projected design ESAL value of 3 million or greater.

Note 2: All mixtures will be a medium traffic design unless otherwise specified in contract documents. Wearing-III material will always be a medium traffic design.

Note 3: Base-I will always be a heavy traffic design and will be tested using six inch diameter specimens in accordance with ASTM D5581.

Note 4: When using a recording chart to determine the flow value, the flow is normally read at the point where the maximum stability begins to decrease. This approach works fine when the stability plot is a smooth rounded curve. However, when aggregate interlocking causes the plot to produce a flat line at the peak stability, the flow value shall be read at the point of initial peak stability. If this method of determining the flow value adversely affects a previously verified design then a new design verification shall be conducted to reaffirm the design tolerances.

Note 5: A Wearing-I heavy traffic design shall have a VFA range of 65 – 76%.

TABLE 401.02.22B
MINIMUM PERCENT VOIDS IN MINERAL AGGREGATE

Size Sieve	Minimum Voids in Mineral Aggregate, Percent
No. 4 - (4.75 mm)	17.0
3/8 in - (9.5 mm)	15.0
½ in - (12.5 mm	14.0
¾ in - (19 mm)	13.0
1 in - (25 mm)	12.0
1 ½ in - (37.5 mm)	11.0
2 in - (50 mm)	10.5

5.0 DETERMINING THE OPTIMUM ASPHALT CONTENT

5.1 Prepare a graphical plot of the following relationships:

- Asphalt Content vs. Percent Air Voids
- Asphalt Content vs. Stability
- Asphalt Content vs. Flow
- Asphalt Content vs. VMA
- Asphalt Content vs. VFA
- Asphalt Content vs. Unit Weight

5.2 From the plot of asphalt content vs. percent air voids, pick the asphalt content that corresponds to the mid-point of the specified design air void criteria of Table 401.02.22A.

5.3 If the corresponding stability, flow, VMA, and VFA values are within the specified design criteria at the asphalt content determined in Section 5.2, then this asphalt content shall be considered the optimum asphalt content for the mix.

5.4 If the design property values determined as per Section 5.3 do not meet the specified criteria at the percent asphalt content determined in Section 5.2, then new mix proportions must be determined and new test data developed.

6.0 REPORT

6.1 The T-400 PMF Form shall include the design property information required in Section 401.4 of the Standard Specifications. The PMF package shall include the following:

6.2 A summary sheet showing the optimum asphalt content determination plus the design properties compared to the design criteria of Table 401.02.22A.

6.3 A Marshall mix design data summary worksheet.

6.4 Worksheets showing calculation for bulk, apparent, and effective specific gravities and absorption of the aggregates used in the mix design.

6.5 Worksheets showing calculations for maximum specific gravities of the mix at different asphalt contents.

6.6 The 0.45 power gradation chart developed for each mix design.

6.7 A worksheet showing the calculations for the combined aggregate of the mix design.

6.8 Worksheets showing the washed sieve analysis results for each aggregate used in the mix design.

6.9 The temperature-viscosity chart for the asphalt used in the mix design. A supplier issued statement containing the mix and compaction temperature recommended for the specific grade of asphalt may be included in lieu of the chart.

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